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**PROCESS
MEASUREMENTS**

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PO Box 1297, Newburgh, NY 12550

TD-100A

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MEASUREMENTS

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PO Box 1297, Newburgh, NY 12550



Macbeth
Color &
Photometry
Division

OF KOLLMORGEN CORPORATION

QuantaLog[®]
Transmission
Densitometer
TD-100A

Operator's &
Service Manual

**OWNER'S MANUAL
FOR THE
OPERATION, MAINTENANCE, AND
TROUBLE-SHOOTING
OF THE
MACBETH QUANTALOG
DENSITOMETER
MODEL TD-100A**



Price

October, 1966

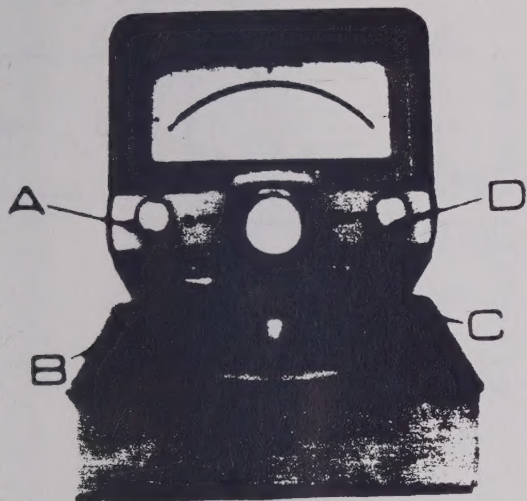
**Operating
Instructions
QUANTALOG MODEL**

TD-100A

Transmission Densitometer

Instrument Zero and Calibration should be adjusted
before each series of measurements

Controls should be operated in the sequence indicated below



- 1** Turn on the instrument using the combination On/Off and Zero Adjust Control (A), and warm up a minimum of 20 minutes. Depress* the snout lever (B) and adjust meter zero. Adjust meter needle reads zero. Release lever.
- 2** Move the Calibration Reference Control (C) towards the rear of the instrument.
- 3** Depress the snout lever (B) and rotate the Calibration Control (D) until the meter reads the density previously determined by the Step Tablet. See "Calibration Reference" in Owner's Manual supplied with instrument.
- 4** Position the sample you wish to measure over the measuring aperture and depress* the snout lever (B). With the snout lever depressed, read the measured density directly from the meter.

*Meter needle normally reads off scale to the left. Snout lever must be depressed through its full travel to actuate meter needle.

Note: Make sure that switch on rear panel is in the proper position for the aperture used.

For detailed instructions and maintenance information see "Owner's Manual" for the Operation, Maintenance, and Trouble Shooting.

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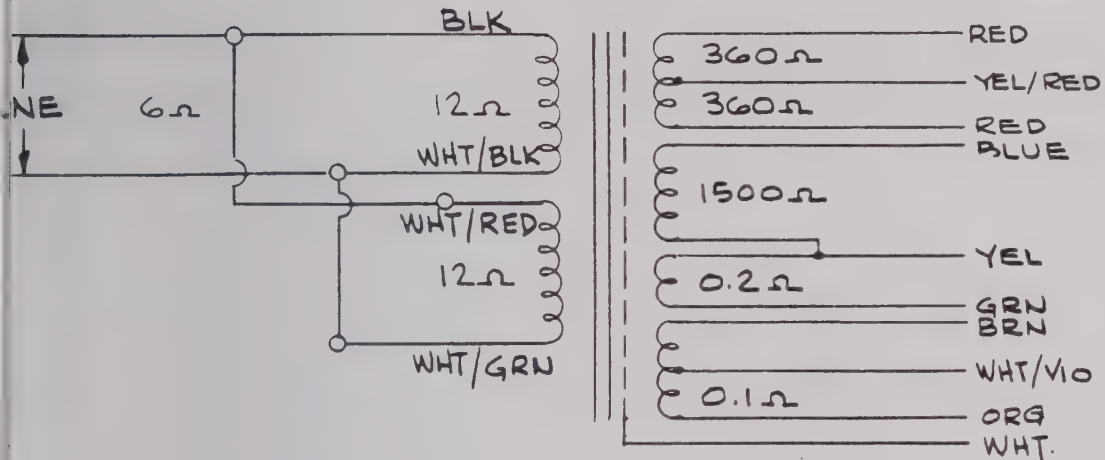
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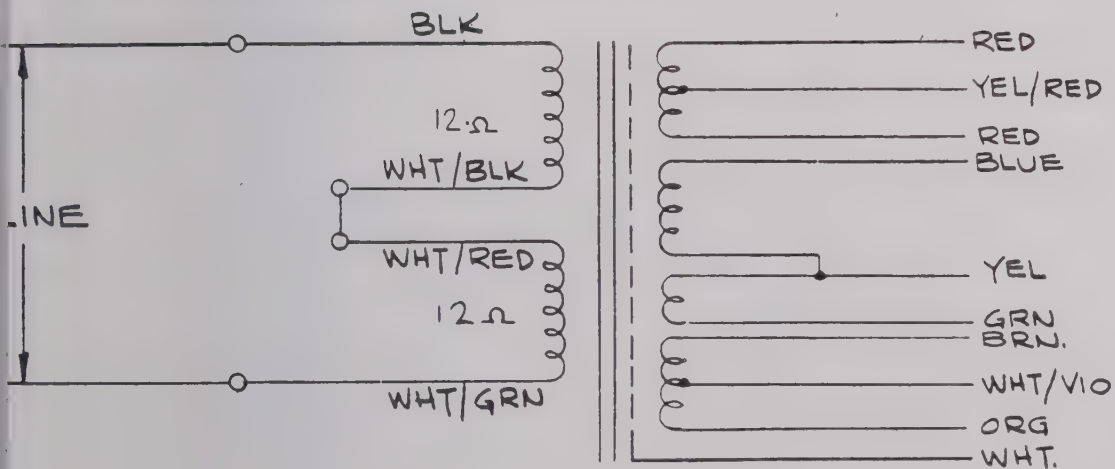
EXHIBIT D

TRANSFORMER SPECIFICATIONS

POWER TRANSFORMER T-1 (115 VOLT OPERATION)



POWER TRANSFORMER T-1 (230 VOLT OPERATION)



CHANGE NO. 1
DATE 8/17/70



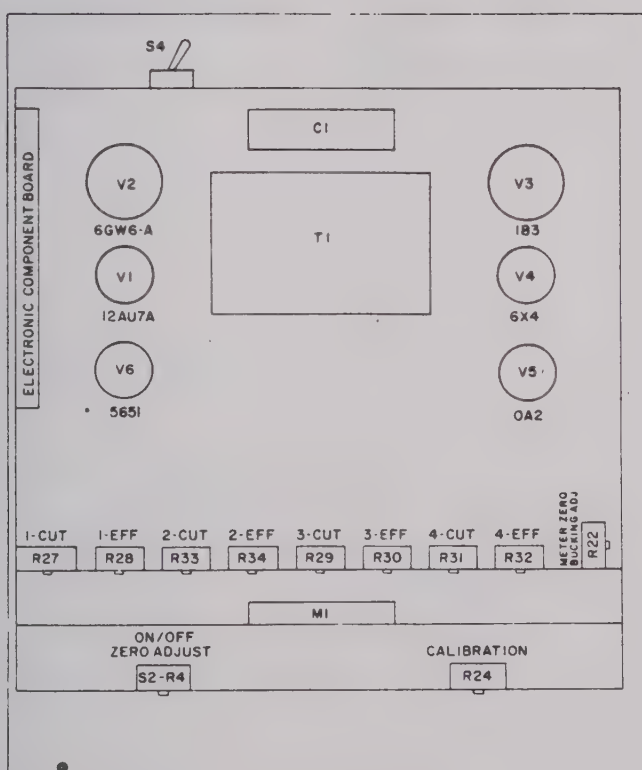
INSTRUCTION BOOK CHANGE NOTICE

MANUAL AFFECTED TD-100A

(ISSUE DATE: 10/1966)

Figure 5

The chassis-layout portion of Figure 5 should be changed to comply with the sketch below.





CHANGE NO. 2
DATE 11/4/70

INSTRUCTION BOOK CHANGE NOTICE

MANUAL AFFECTED TD-100A

(ISSUE DATE: 10/66)

1. Parts List

The Part Number and Description entries for Ref. Symbol R35 should be changed in accordance with:

DESIG.	MACBETH PART NO.	DESCRIPTION
R35	36272000	RESISTOR, FIXED, COMP: 2.7K ohm, 1/2 watt, $\pm$ 5%

2. Parts List

The following information should be added to the "Optical" portion of the Parts List.

DESIG.	MACBETH PART NO.	DESCRIPTION	MANUFACTURER
	21002101	INSERT, APERTURE: .0394-1mm	MACBETH

3. Figure 5

Resistor R35 located in the negative input lead to Meter M1 should be changed from 6.8K to 2.7K.



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CHANGE NO. 3
DATE 12/17/70



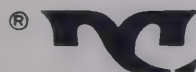
INSTRUCTION BOOK CHANGE NOTICE

MANUAL AFFECTED TD-100A

(ISSUE DATE: 10/66)

The following information should be added to the "Optical" portion of the Parts List.

REF SYMBOL	MACBETH PART NO.	DESCRIPTION
	21002201	INSERT, APERTURE: .0787-2mm
	21002302	INSERT, APERTURE: .1181-3mm



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ANGE NO. #4
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INSTRUCTION BOOK CHANGE NOTICE

ANUAL AFFECTED TD-100A

(ISSUE DATE: 10/66)

1. Parts List. ELECTRICAL - ELECTRONIC

a. The Part Number and Description entries for Ref. Symbol R5 should be changed in accordance with:

REF. SYMBOL	MACBETH PART NO.	DESCRIPTION
R5	36473000	RESISTOR, Fixed, Comp. 47K ohm, 1/2 watt, ±10%

b. The Part Number and Description entries for Ref. Symbol R36 should be changed in accordance with:

REF. SYMBOL	MACBETH PART NO.	DESCRIPTION
R36	36103003	RESISTOR, Fixed, Comp. 10K ohm, 1/2 watt, ±10%

c. The Part Number, Description, and Manufacturer entries for Ref. Symbol V7 should be changed in accordance with:

REF. SYMBOL	MACBETH PART NO.	DESCRIPTION	MANUFACTURER
V7	10000450	Light Source Subassembly*	Macbeth*
*This light source is pre-selected to meet design criteria of the TD-100A. V7 is available only from the Macbeth Corporation or from an authorized dealer.			



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2. Figure 5.

Resistor R36 should be changed from 22K to 10K.

3. Figure 7.

Resistor R35 should be changed from 6.8K to 2.7K

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I — GENERAL INFORMATION

A-INTRODUCTION

This manual, which includes operating instructions, construction details, maintenance data and trouble-shooting information, has been prepared to enable you to enjoy optimum performance from your Macbeth QuantaLog Transmission Densitometer, Model TD-100A. The TD-100A has been developed to fill the need for an easy-to-operate, reliable, precision instrument for measuring the visual densities of materials. The information set forth in this manual will serve you over the years, and the few minutes you invest now to acquaint yourself with its contents will reap rewards for you throughout the life of this fine instrument.

B-APPLICATIONS

The TD-100A has application in areas where the measurement of diffuse visual transmission density is critical for establishing and/or insuring consistent product quality.

For application information, write to the Macbeth Instrument Corporation, Newburgh, N.Y., 12550, requesting specific assistance. These inquiries should be directed to the attention of the Technical Sales and Service Department.

C-GENERAL PRINCIPLES OF OPERATION

This single-unit transmission densitometer is designed to make it possible for an unskilled operator to make rapid, accurate, and reproducible measurements since it eliminates the operator errors and variables normally associated with conventional densitometers. This has been accomplished by minimizing the number of operator controls and through the engineering development of a measuring technique which prevents operator variables from affecting the precision and accuracy inherent in the optical and electronic design of the instrument itself.

The readings taken with your TD-100A indicate Diffuse Visual Transmission density, and the linear meter scale, with evenly-spaced graduations, minimizes possible operator confusion. A mirrored meter scale enables the operator to make accurate and reproducible meter readings, since parallax errors are avoided.

D-OPERATING REQUIREMENTS

1 — Power Consumption

The total power consumed by the TD-100A is approximately 60 Watts. This includes the power required to operate the electronic circuits, the optical system light source, and the anti-fatigue lamp.

2 — Operating Voltages

The power transformer of the TD-100A has been designed for either 115 or 230 Volt operation, at power line frequencies of 50 and 60 Cycles/sec. The data tag on the back of each instrument indicates the specific operating voltage for which its transformer primary has been wired. (Refer to Section III - D of this manual for instructions if this operating voltage is to be changed.)

3 — Voltage Regulation

The electronic power supply of the TD-100A is self-regulated and hence is not affected by normal line voltage variations. However, line voltage variations will affect the stability of the energy radiated by the optical system's light source. Therefore, a voltage regulator must be used to prevent these fluctuations from causing reading errors. A simple 60 Volt-Ampere regulator is adequate for this purpose.

4 — Ambient Illumination

The TD-100A is designed for operation under all normal conditions of ambient illumination. Its performance specifications are equally unaffected by operation in either a darkroom (meter scale is not illuminated, therefore some form of illumination is required when reading the scale under these conditions) or by a sunlit window.

E-PERFORMANCE SPECIFICATIONS

1 — Optical

(a) The geometry of the optical system meets the ASA Standard PH2-19-1959 for Measuring Diffuse Visual Transmission Density.

(b) The instrument is equipped with a Wratten #106 filter. This filter is recommended for general purpose visual response densitometry.

2 — Meter Scale

(a) All meter readings are made directly from a single scale. This eliminates the reading errors that an operator can make in using an instrument that requires range changing.

(b) A mirrored meter scale enables the operator to make accurate and reproducible readings, since parallax readings are avoided.

(c) The linear 0 - 4.0 density scale is divided into 200 graduations, each equal to 0.02 density units. Instrument readings are precise within a tolerance of 0.02 density units, and reliable operator readings can be made with a repeatability of 0.01 density units.

(d) A second scale giving percent transmission values, is printed below the optical density scale.

3 — Circular Stage Diffuser

(a) Brightness of approximately 100 foot-lamberts.

(b) Circular stage of 3½ inch diameter.

4 — Aperture

A circular aperture of 2mm (0.079 in.) is installed, which is removable for replacement (three sizes supplied).

5 — Sample Sizes

The throat clearance is 11 inches, so that it is possible to read the center of a sample which is up to 22 inches wide, and of any length.

6 — Factory Testing

Each sub-assembly of the TD-100A is inspected through its various stages of fabrication. After assembly, every TD-100A is operated for a period which is equivalent to a minimum of several weeks of normal service. Satisfactory completion of this operating test qualifies an instrument for final calibration and testing by our Production Department.

Every instrument is then submitted to our Quality Assurance Inspectors whose acceptance guarantees our customers that each TD-100A shipped meets the exacting performance specifications described above.

F-ACCESSORIES SUPPLIED

The purchase price of your TD-100A includes the following accessories (shown in photo on title page) which you will find enclosed in the shipping carton:

- 1-One Instrument Dust Cover
- 2-One Owner's Manual and Warranty Card
- 3-A transparent Envelope with Simple Operating Instructions
- 4-An Envelope Containing One 1mm (0.0394 in), One 3mm (0.118 in.) Diameter Aperture Disc and pressure sensitive tags
- 5-One Calibrated Step Tablet (0-4.0 Density Range)

II — OPERATING INSTRUCTIONS

A-FUNCTION AND USE OF OPERATING CONTROLS

The operating controls for the TD-100A are located on the front of the main electronics housing (see Fig. 1). Therefore all controls are always in full view and within easy reach of the operator. The function of these controls is described below and they should be operated in the sequence in which they are presented:

1 — Zero Adjust

This control performs a dual function. It is a combined power On-Off switch and ZERO ADJUST control.

(a) Rotating this control clockwise supplies AC power to the instrument after it has been plugged into a suitable voltage regulator (for details see Fig. 5 of this manual).

(b) The ZERO ADJUST control must be rotated further clockwise to set the meter for a zero scale reading. This is done with the snout lever in the depressed position (see Fig. 4). Note that with no sample over the aperture, the meter continues to read below Zero until the snout lever is fully depressed. This is normal and insures against an erroneous ZERO ADJUST setting. (See Section III C-8 of this manual for details).

2 — Calibration

The CALIBRATION control is used to adjust the meter pointer to read a specific up-scale density reading for which the instrument was calibrated at the factory. This control is set as follows:

- (a) Place the step marked "Calib" over the aperture and depress the snout.
- (b) Adjust the calibration control until the meter reads the density indicated for this step.
- (c) Recheck your Zero Adjust control setting by repeating 1b above, and recheck the calibration control setting by repeating steps 2a and 2b above.

3 — Calibration Reference Control

Tags are furnished in the envelope containing the spare apertures. It is the responsibility of the user of the instrument to assign the proper density value number to the tag and periodically check the accuracy of this assigned number weekly. The assigning of this density number is done in the following fashion:

- (a) Allow the instrument to warm up one-half hour.
- (b) With the proper aperture in place, zero the instrument as in 1b above.
- (c) Using the step on the wedge marked "calib", adjust the calibration control to read this value (2b above).
- (d) Check zero and the calibration step again to insure the controls are properly adjusted.
- (e) Remove step wedge, depress snout lever and push calibration reference lever toward rear of instrument. Note and record the reading on one of the pressure sensitive tags referred to above and apply this tag to the end of the calibration reference lever.
- (f) Density readings are made with the calibration lever in its fully forward position.

For quick reference of the instrument throughout the day, the calibration reference would be inserted (by pushing the lever to rear of instrument) and used to properly adjust the calibration control. The accuracy of the calibration reference value should be checked weekly by repeating the above steps a through f.

The two basic purposes for this control are to (1) eliminate continuous use of the calibrated standard step wedge and (2) provide a fast and accurate density reference for adjustment of the calibration control.

B-WARM-UP AND PERIODIC CALIBRATION CHECKS

The electronics system of the TD-100A has been designed for rapid warm-up, but at least thirty (30) minutes should be allowed to permit components to arrive at thermal equilibrium.

This is a manually-operated and manually-calibrated instrument. Therefore, it is recommended that the ZERO ADJUST and CALIBRATION control settings be checked several times during the day, and reset whenever necessary to ensure that it is performing according to specifications.

C-CHANGING APERTURE DISCS

The operator may proceed to measure the density of samples after the above operating instructions have been complied with.

These density measurements will be for the 2mm diameter aperture disc that is normally installed in the densitometer when delivered. This aperture disc can be replaced by either the 1mm or the 3mm aperture by removing the circular stage diffuser and pushing out the 2mm diameter aperture disc. A rod of soft material, wood or plastic, should be used to push the aperture discs out of the circular stage diffuser or permanent damage to the aperture itself may result.

When changing apertures in the TD-100A, a change in light level has to be affected. A switch, located on the rear panel of the TD-100A, provides the proper light-level for the 2 or 3mm, and the 1mm aperture. (see figure 8)

D-OPERATION IN DARKROOM

When operating the TD-100A in a dark-room, it is possible to turn the optical system light-source off, while the electronics are kept in a "stand-by" condition. The middle position of the 3 position switch, described above under "C", (figure 8) is marked "OFF" and provides for this condition. Make sure that the snout lever is in the "UP" position and that the meter needle is to the left of "0". If the needle is to the right of "0", refer to section IV, A-4 for replacement of the Anti Fatigue light-source.

When using highly sensitive panchromatic materials, please make sure that the slight glow from the electronic tubes, which might be visible through the back, does not interfere with your dark-room operation. Also, a slight drift may be encountered after the light-source is turned on, this is due to the thermal lag of the filament and other light-source components.

III — INSTRUMENT SYSTEMS PRINCIPLES AND CONSTRUCTION DETAILS

A-THEORY

The theory of operation of the TD-100A electronic circuitry is based upon the use of a photomultiplier in a feedback circuit which automatically adjusts the dynode voltage applied to a photomultiplier so as to maintain a constant anode current. The dynode voltage required to maintain a constant current for any particular amount of light falling on its photosensitive cathode is used as a measure of the optical density of a sample placed between a light source and the photomultiplier itself. Figure No. 3 is a block diagram of this over-all system. If, for example, the light flux falling upon the photosensitive surface of the photomultiplier decreases as when a sample is introduced, the input signal of the voltage amplifier decreases. This signal is amplified and fed to the input of the power amplifier which controls the output voltage of the high voltage power supply. For the case cited, the output voltage of the high voltage power supply increases in order to maintain a constant anode current within the photomultiplier tube. The voltmeter which constantly measures this voltage will now indicate a higher voltage. Since the meter is calibrated in density units, this increase in voltage indicates an increase in density. The dynode voltage for a typical TD-100A will vary between approximately 220 and 800 Volts for samples whose optical densities fall between 0. and 4.0.

This is not a completely linear relationship, however, and therefore a compensating circuit is used to calibrate the voltmeter readings to a given density standard.

B-DETAILS OF OPTICAL SYSTEM

1 — Imaging and Collection Optics

All details of the TD-100A optical system are schematically depicted in Figure 4, and Figure 11 is a photograph of the imaging optics.

The light source (LS 1) used in the optical system is a prefocussed incandescent tungsten lamp. One end of the wire which supplies current to the lamp is soldered to the contact at the base of the lamp. The other end of this wire has a spade lug which is screwed down to a terminal strip. Energy from this light source is focused in the plane of the aperture disc by an imaging lens (L1) after passing through a heat absorber and dichroic filter. A mirror between the imaging lens and the aperture merely serves to fold the optical system.

The collection cone is held against the sample by a spring (not shown) when measurements are being made. The light transmitted through the sample is first scattered by a pot opal diffuser in the collection cone, which is positioned nearly in contact with the sample, and then reflected by the polished inside surface of the collection cone. (Note that a Neoprene "O" ring is used to seal out stray light at the surface of the sample, and that stray light is excluded from the photomultiplier housing by a light trap located at the top of the telescoping snout mechanism). A second lens (L2) serves to direct the light reflected by the collection cone onto the surface of the photomultiplier tube after it passes through the visual filter.

2 — Calibration Reference

A movable neutral density filter can be manually inserted between the lens L2 and the photomultiplier tube by means of the CALIBRATION REFERENCE control. This filter, the density of which has been assigned by the operator according to the instructions under II A4, provides the operator with an internal calibration reference, thereby circumventing the problems of maintaining auxiliary reference standards in production areas.

3 — Circular Stage Diffuser

A circular stage diffuser is used to uniformly illuminate the sample, thereby facilitating its accurate positioning over the aperture disc. Energy radiated from the back and sides of the optical system's light source (LS 1) is directed by the light source and stage illumination reflectors onto the bottom surface of the circular stage diffuser. Therefore, no auxiliary light source is required for stage illumination.

C-DETAILS OF ELECTRONIC CIRCUITS

The details of the electronic circuits are covered below under separate headings which correspond to the blocks shown in the overall system block diagram (Figure No. 3).

1 — Photomultiplier Tube

A simple phototube consists of two elements, a photoelectric emitter, or cathode, and a collecting anode, enclosed within an evacuated glass envelope. If sufficient potential is applied between these elements, current will flow through the tube when its cathode is bombarded by incident photons. This current is extremely small when the cathode is exposed to low light levels, and must be amplified by electronic circuits external to the tube itself. In a photomultiplier tube, however, amplification of the photoelectric current is accomplished by the addition of a dynode structure between the cathode and anode of the simple phototube. This structure usually consists of nine or more dynode stages, each operating at a slightly higher potential than the preceding element (see Figure No. 5). These dynodes emit copious amounts of electrons by secondary emission when excited by incident electrons. The dynodes are shaped so that the electrons leaving one dynode are guided to the next by an electrostatic focusing action. It is possible to realize a 400,000 times amplification of the initial photocathode current within a photomultiplier tube when it is operated at approximately 100 Volts/dynode stage. A photomultiplier tube is usually employed as a current-generating device in most circuit applications. That is, a constant dynode voltage is applied to the tube, and its current output is used as a measure of the light flux incident upon its photo-cathode surface (I in Figure No. 3). This relationship between flux falling on the photo-cathode (I) and tube current is essentially linear. If, however, the tube current is related back to the flux that is incident upon a sample (I in

Figure No. 3) then the relationship between I and tube current is logarithmic. In other words, if the output current of the photomultiplier tube is used in a photometer to directly measure the transmission density of a sample, then the density scale of the photometer must be logarithmic (sample density) $D = \log(I)$. This is undesirable since scale markings will be spread out at low density readings, and the optical density extremely crowded at high density readings.

This undesirable situation can be overcome, however, by employing a photomultiplier tube as a constant current device and measuring its dynode voltage instead. In this circuit application, the dynode voltage is constantly adjusted electronically to maintain a constant current through the tube, regardless of the amount of light flux incident upon its photocathode. The relationship between dynode voltage and optical density now becomes very nearly linear since the dynode voltage is approximately equal to the negative logarithm of the light flux incident upon the sample (I).

Hence, the TD-100A employs a highly sensitive photomultiplier detector in a unique dynode feedback circuit whose output is very nearly linear with transmission density. The other advantages of this circuit are described below.

2 — Dynode Feedback Circuit

There are several advantages to the use of a dynode feedback circuit for operating a photomultiplier in addition to the fact that this circuit yields a nearly linear relationship between transmission optical density and dynode voltage.

First, this mode of operation is tantamount to operating the photomultiplier in the conventional way, but under the ideal conditions of constant dynode voltage and with a constant level of incident flux. The result is maximum stability within the tube itself.

Second, this circuit eliminates the need for the precision-stabilized high voltage source required in conventional circuits.

Third, this feedback feature permits operation of the photomultiplier at greatly reduced dynode voltages during the periods between density readings, thereby minimizing the deleterious effects of photomultiplier fatigue (see Section III C8).

The photomultiplier tube in this instrument is used in a feedback loop which automatically adjusts its dynode voltage to keep the anode current constant (Figure No. 5). A signal is developed across R1 which is then amplified in the d.c. amplifier stage using a 12AU7 (V1). This amplified signal is fed to the input of a 6GW6-A power amplifier tube (V2). The plate circuit of this stage consists of the high voltage power supply, which uses a 1B3 rectifier (V3), and an impedance consisting of the dynode resistor string (R12 through R20).

If less light flux is received (increase in sample density) by the photomultiplier tube, then the signal appearing across R1 decreases (becomes less negative). This amplified signal appears at the input of V2 as a decrease in bias (grid becomes more positive) and hence the plate current of V2 increases. This increases the current in the dynode string which increases the voltage across the dynode resistors. Therefore, the gain of the photomultiplier tube is increased and the anode current is restored to its original value.

3 — Compensating Circuit

If the operating characteristics of the dynode feedback circuit are plotted as Dynode Voltage vs. Diffuse Transmission Density, it will be seen that a perfectly linear relationship does not exist (Exhibit A). Note that the curve shown for the uncompensated dynode voltage is essentially logarithmic. Since it is desirable to obtain meter readings that are equally spaced for equal increments of density, a compensating circuit is used to obtain the instrument characteristics that are represented by the dashed-line labeled "Compensated Dynode Voltage Characteristics."

Note in Figure 5 that the microammeter, in series with a 24K (R26) resistor and a 1.6 Meg. (R23) resistor is connected across the dynode string resistors (Point X to Ground). This is in effect a voltmeter which would yield a curve similar to the one shown in Exhibit A for uncompensated dynode voltage characteristics. (R35 is used in series with the meter M1 to effectively increase its internal impedance).

The compensating circuitry consists of independent, parallel circuits bounded by a dashed line which shunt that portion of the dynode voltage which appears across the meter.

Each contains two potentiometers known respectively as a "CUT-IN" potentiometer (R27, R33, R29 and R31) and an "EFFECT" potentiometer (R28, R34, R30 and R32); and a diode (CR1, CR2, CR3, and CR4). These potentiometers are set (see "Calibration Procedure" outlined in Section IV C) at the points indicated on the curve in Exhibit A to yield a straight line for meter readings vs. diffuse transmission density.

The four cut-in potentiometers (R27, R33, R29, R31) are connected across a zener diode (CR5) which provides a constant reference voltage of -- 11 Volts for the compensating circuitry. The setting of each cut-in potentiometer determines the voltage at which a particular diode will begin to conduct, and the corresponding effect potentiometer determines how much current it will conduct. For example, the setting of R27 determines when CR1 will begin to conduct, and the setting of the effect potentiometer R28 determines its conduction current. The instrument meter measures the voltage appearing between Point X and Ground.

4 — Calibration Control Circuit

The CALIBRATION control circuit, which shunts the meter, consists of a fixed resistor (R25) and the CALIBRATION control potentiometer (R24). This control is used as a fine adjustment for the voltage appearing across the meter while reading the density indicated for the internal calibration reference described in Section II A4.

5 — Meter Zero Bucking Voltage Adjust Circuit

The meter Zero bucking voltage adjust circuit consists of a fixed resistor (R21) and a potentiometer (R22) connected between a regulated voltage of approximately 85 Volts and the instrument meter. This circuit is used as a source of bucking voltage to set up the meter Zero during initial factory calibration or when a photomultiplier tube is changed (See Section IV C).

6 — Zero Adjust Circuit

The ZERO ADJUST circuit consists of a fixed resistor (R5) and a potentiometer (R4) connected to a regulated voltage of approximately 140 Volts. The setting of the ZERO ADJUST potentiometer sets the operating bias of the first amplifier tube (VI) which provides for an operator adjustment to compensate for gradual aging of the light source or slight changes in circuit sensitivity.

7 — Regulated Power Supply

The regulated power supply consists of a full-wave 6X4 rectifier tube (V4), and RC filter (R11 and C2), and two voltage regulator tubes (V5 and V6). This power supply furnishes all of the d.c. requirements for the voltage and power amplifier stages, as well as for the compensating and bucking circuits. The high degree of circuit stability realized in this instrument is determined by the excellent regulation of this power supply. As stated earlier, an external line voltage regulator is required only to stabilize the intensity of the optical system light source.

8 — Anti-Fatigue Light

All photodetectors, including photomultipliers, may exhibit a change in their anode currents with no change in the amount of incident light flux. This effect is commonly known as fatigue. Several factors affect the degree and rapidity of these changes, but fatigue in a photomultiplier appears to be principally determined by the average tube current and the material used to coat the dynode surfaces. Fatigue can be either an increase or decrease in sensitivity, although the latter is by far the more common situation.

It appears that most photomultiplier fatigue is the result of a change in the secondary-emission characteristics of the dynode stages. This is probably caused by migration of cesium from the dynodes to the other surfaces within the tube, thereby effectively reducing the tube's amplifying capabilities. The effects of this type of fatigue can be mitigated under practical operating conditions by applying the required dynode potentials only while readings are actually being made, and by operating the tube at the lowest possible dynode voltages.

The dynode feedback circuitry of this instrument, together with an anti-fatigue light (LS 2), permit operation of the photomultiplier tube on a "stand-by" basis between readings. The anti-fatigue lamp (see Figure No. 4) is positioned next to the photomultiplier tube, and is energized through S3, a micro-switch (see Figures 5 and 6) whenever the snout lever is in the "up" position. The shield on this lamp (LS 2) is rotated until the dynode feedback circuit automatically adjusts the dynode at approximately 190 Volts (30 Volts less than the dynode voltage for Zero density) in the "stand-by" position.

The anti-fatigue light and dynode feedback circuit, together with the use of a very efficient optical system, virtually eliminates the effects of photomultiplier fatigue in the TD-100A.

D-DETAILS OF ELECTRICAL CIRCUITS

The circuit details of the electrical system are covered in Figure No. 5. All input a.c. power is fed through a three-prong linecord plug. S1 is a safety interlock switch which is in the "open" position whenever the instrument cover is removed (see Figure No. 8). The instrument fuse F1 is located on the rear of the Chassis (see Figure No. 8). S2 is the main power "On-Off" switch, located on the front, left-hand side of the electronics housing (see Figure No. 1), and is ganged with the ZERO ADJUST potentiometer.

1 — 115 or 230 Volt Operation

Note that the power transformer (T1) primary is shown wired for 115 Volt operation. If the instrument is to be operated from 230 Volts, this wiring must be changed in accordance with the information tabulated in "Transformer Specifications - Exhibit D", and referring to Figure No. 9.

2 — Light Source Wiring

The optical system light source LS 1 is operated from the 6.0 Volt filament winding of T1. The full voltage from this winding is supplied to the light-source through switch S4, position #3, (see figure 5) when the 1mm aperture is used. With either the 2 or 3mm aperture, the 6.0 Voltage is applied through switch S4, position #1, and the dropping resistor R37. (figure 5). Switch S4, position #2, provides for the stand-by position.

3 — Anti-Fatigue Light Source Wiring

The anti-fatigue light source (LS 2) is operated from the 7.3 Volt secondary of the power transformer (T1) (see Figure 5). Power from this winding is supplied to the anti-fatigue lamp through a microswitch (S3) which is located on the snout mechanism (see Figure 6). S3 is normally closed with the collection cone in the "up" position so that the anti-fatigue light source is in operation at all times except when making density measurements.

E-MECHANICAL DETAILS

The TD-100A consists of a shallow, aluminum base frame which houses the imaging portions of the optical system, as well as the reflectors used to illuminate the circular stage diffuser. The light collection optics, photodetector, and all electronic components are housed in an aluminum die-casting which is permanently bolted to the $\frac{1}{4}$ inch aluminum stage base. The instrument cover, including the perforated front and back plates, is of sheet metal construction. This cover is held in place by two knurled cover screws which fasten to the die-cast housing. The entire instrument is finished in a baked, two-tone metallic blue-gray paint.

1 — Snout Mechanism

The details of the snout mechanism are shown in Figure No. 6. The probe snout is fastened to the underside of the photo-multiplier housing (see Figure No. 4). The telescoping collection cone is moved within the probe snout by manually applying pressure to the snout lever through the finger rest (Figure No. 6). A pre-determined force of approximately one pound is applied between the aperture light seal and the aperture disc by means of the snout tension spring. If the snout lever is depressed beyond the point where contact is established, a clutch override action permits the snout lever to be depressed until the cam hits a mechanical stop (Figure No. 6). Therefore, this mechanism provides a constant pressure between the aperture seal and the aperture disc which is independent of the force applied by the operator. The collection cone is returned by the snout return spring when the snout lever is released (Figure No. 6).

2 — Microswitch Cam

A cam is attached to the snout lever for operation of the snout microswitch (S3) (Figure 6). One face of this cam actuates the microswitch when the snout lever is depressed and a second face serves as a mechanical stop for the snout mechanism when the snout lever is released (Figure No. 6.)

3 — Calibration Reference Control

The CALIBRATION REFERENCE control consists of a filter holder, a pivot shaft with a two-position detent, and an actuating lever (see Figure No. 2 and No. 4). This mechanism is in effect a movable filter which is manually actuated by the operator during setting of the CALIBRATION control. This control places the calibrated filter in the measuring beam when it is moved backward, and returns to a "stand-by" position when it is moved forward.

IV — MAINTENANCE INTRUCTIONS

A-OPTICAL SYSTEM

The optical system of this instrument requires infrequent but regular maintenance and the occasions for component replacement will be rare. Instructions are given below should component replacement become necessary, together with the attendant information required for effecting replacements.

1 — Light Source Replacement

Spare lamps for the optical system's light source should be obtained from your authorized MACBETH dealer, or ordered directly from the MACBETH INSTRUMENT CORPORATION, NEWBURGH, N.Y. 12550. A burned-out light source is easily replaced as follows:

- (a) Remove base cover plate retaining screw.
- (b) Slide base cover backward and free completely from the instrument.
- (c) Loosen screw (do not remove) which fastens the spade lug connector on the light source wire to the terminal strip.
- (d) Remove the light source by twisting it counter clockwise.
- (e) Remove the lamp, together with its wiring.
- (f) Slide the spade lug connector of your lamp replacement unit under the screw on the terminal strip and secure by tightening the screw.
- (g) Follow procedure given below for light source positioning and focusing.

2 — Light Source Positioning and Focusing

The optical system's light source is pre-focused, however, some positioning and focusing adjustments might be required whenever replacement becomes necessary. The adjustments should be made as follows:

- (a) Set the instrument on its side.
- (b) Loosen the two screws which fasten the light source bracket to the stage base.
- (c) Move the light source bracket along the optical axis until the filament is properly focused in the plane of the aperture.
- (d) Tighten the two screws which fasten the light source bracket to the stage base.
- (e) Final positioning is made photometrically by depressing the snout lever and setting the light source for minimum meter reading.
- (f) Replace the base cover plate and retaining screw.

3 — Changing Light Source Intensity

A switch located on the rear chassis panel of the TD-100A, (S4 in figure 5) provides 2 lightsource intensities which are pre-set for use with the 2 or 3mm aperture and the 1mm aperture. A third position turns the lightsource off completely, thus providing essentially a "safe dark-room" condition.

4 — Anti-Fatigue Light Source Replacement

The life of the anti-fatigue light source (LS 2) is in excess of 3,000 hours at its rated voltage of 14 Volts. Since in the TD-100A this lamp is operated at about 50% of its rated voltage, its life is expected to be virtually infinite. It can be replaced by removing the photomultiplier housing and unscrewing it from its socket. Care should be exercised in replacing the light shield so that its original position is restored.

5 — Periodic Inspection and Cleaning

It is advisable to check the optical system of your instrument on a periodic basis, and the following quarterly inspection is suggested:

1. Remove circular stage diffuser and inspect the aperture disc and folding mirror for damage such as scratches and dirt.
2. Remove the base cover plate and inspect the light source, reflectors, heat-absorbing and dichroic filters, and lens for possible cracks or accumulation of dirt or moisture.
3. Check for possible light leaks at the aperture light seal by measuring Step No. 18 on your calibrated step tablet, with and without light from a flashlight falling on the aperture disc.
4. Remove the photomultiplier housing by loosening the photomultiplier housing screw (see Figure No. 4).
5. Remove the photomultiplier tube and inspect the neutral density filter of the CALIBRATION REFERENCE control for cracks or dirt.
6. Inspect the lens (L2) for cleanliness.
7. Replace the photomultiplier tube, photomultiplier housing, and filter turret.

B-ELECTRONICS

All electronic components, but one, are accessible for replacement by simply removing the instrument cover (Figure No. 9). It is not necessary to remove the chassis unless R11 must be replaced. This is a 10 Watt, wire-wound resistor, however, and its failure is highly improbable.

1 — Tube Replacement

A tube layout drawing is fastened to the inside of the instrument cover as an aid in identifying each of the vacuum tubes. Note that this drawing also gives the identity and location of all potentiometers and transformers.

2 — Electronic Components Board

The components of the electronics system are mounted to a board which is a separate sub-assembly. This board can be tilted back by first loosening the retaining screw located toward the front end of the chassis (Figure No. 8). Each of the components is identified in Figure No. 7.

C-CALIBRATION PROCEDURE

Calibration of the TD-100A is required whenever a photo-multiplier tube is replaced. It is also advisable to check the calibration of your instrument, using the calibrated step tablet, whenever any other critical electrical components are replaced, such as rectifier tubes, transformers, capacitors, or diodes. The only auxiliary equipment required to calibrate your instrument is a voltmeter which has a sensitivity of 20,000 Ohms per Volt, such as Simpson Model 262, Triplet Model 630-PL, Weston Model 980, or other comparable multimeter. The step by step procedure for calibration is as follows:

1. Remove the cover of the instrument by removing the cover retaining screws. This releases the safety interlock switch S1 making the instrument inoperable. It is necessary to keep this switch actuated with a rod of insulated material, such as wood or plastic, to effect calibration of the instrument.
2. Plug the TD-100A into a voltage regulator which has been plugged into the power line (a 60 Volt-ampere capacity voltage regulator must be selected for operation on either 115 Volt or 230 Volt 50-60 Cycle operation).
3. Plug the DC voltmeter into the dynode voltage jacks which are located on the rear of the chassis (see Figure 8).
4. Set the ZERO ADJUST control (R-4) at mid-range.
5. Depress the snout lever.
6. Adjust the meter zero bucking adjust potentiometer with a screwdriver (R-22) until the meter reads zero. (This control is located on the righthand side of the meter bracket, behind the bracket itself).
7. Reset the ZERO ADJUST control (R-4) until the voltmeter reads 230 Volts.
8. Reset the meter zero bucking adjust potentiometer until the meter reads zero.
9. Set all cut-in potentiometers (R-27, R-29 and R-31) fully clockwise, and set all effect potentiometers (R-28, R-34, R-30 and R-32) in mid-position. These

controls are all located on top of the meter bracket (see Figure 10) and are identified by a label that indicates which step of the calibrated step tablet they should be adjusted at.

10. Set the CALIBRATION control (R-24) for a meter reading corresponding to the density indicated for Step No. 2 of the step tablet. (Density of approximately 0.45 density units).
11. Select Step No. 4 on your calibrated step tablet. This step has an indicated density of approximately 0.85 density units.
12. Rotate the first cut-in potentiometer (R-27) counterclockwise until you obtain a meter reading corresponding to the step density, plus 0.02 density units.
13. Select Step No. 6 on your calibrated step tablet which has an indicated density of approximately 1.25 density units, and rotate the first effect potentiometer (R-28) until you obtain a meter reading corresponding to the step density plus 0.02 density units.
14. Move to Step No. 8 which has an indicated density of approximately 1.60 density units and rotate the second cut-in Potentiometer (R-33) counterclockwise until you obtain a meter reading corresponding to the step density plus 0.02 density units.
15. Move to Step No. 10 which has an indicated density of approximately 2.00 density units and rotate the second effect potentiometer (R-34) counterclockwise until you obtain a meter reading corresponding to the step density, plus 0.02 density units.
16. Move to Step No. 12 which has an indicated density of approximately 2.40 density units and rotate the third cut-in potentiometer (R-29) counterclockwise until you obtain a meter reading corresponding to the step density, plus 0.01 density units.
17. Move to Step No. 14 which has an indicated density of approximately 2.80 density units and rotate the third effect potentiometer (R-30) counterclockwise until you obtain a meter reading corresponding to the step density, plus 0.01 density units.

18. Move to Step No. 16 which has an indicated density of approximately 3.20 density units and rotate the fourth cut-in potentiometer (R-31) counterclockwise until you obtain a meter reading corresponding to the actual step density.
19. Move to Step No. 18 which has an indicated density of approximately 3.60 density units and then rotate the fourth effect potentiometer (R-32) counterclockwise until you obtain a meter reading corresponding to the actual step density.

It may be necessary to repeat the entire calibration procedure once or twice until you have attained proficiency through experience. However, the TD-100A is simple to recalibrate and its performance specifications as outlined in Section 1 can be quickly realized by completing the calibration procedure described above.

D-TROUBLE-SHOOTING

All trouble-shooting can be accomplished without removing the chassis from the main housing. A circuit TROUBLE-REMEDY chart is given in Exhibit B as a guide for isolating possible malfunctions which may occur. A chart of voltage and resistance measurements is given in Exhibit C to assist in identifying individual defective components. The normal operating voltages are given in Figures 5 and 7, as well as in the Electrical and Electronic Schematic drawing which is fastened to the inside of the instrument cover.

V — REPLACEABLE PARTS LIST

This section describes the major replaceable parts for your TD-100A which are listed as electrical-electronic, optical, and mechanical components. All parts listed under electrical-electronic may be purchased directly from the manufacturers indicated except for V7, T1, LS1, and M1. V7 is a photomultiplier which must be specially selected to ensure that your TD-100A will continue to meet its performance specifications. Order this item directly from the Macbeth Instrument Corporation, indicating that it is to be used in a TD-100A instrument. All items listed under optical and mechanical are Macbeth Instrument Corporation stock items and therefore should be ordered directly from the Macbeth Instrument Corporation or your authorized Macbeth dealer.

REPLACEABLE PARTS LIST

TD-100A

ELECTRICAL - ELECTRONIC

Desig.	Part No.	Name of Part and Description	Function	Manufac
C1	06100800	Capacitor, Paper 0.1 Mfd., 1600 Volts	High Voltage Ripple Filter	Pyrami #CT16
C2	06200600	Capacitor, Electrolytic 20 Mfd., 450 Volts	B+ Ripple Filter	Sprague #TVA-1
CR1, CR2, CR3, CR4	41100001	Diodes, Dual #6RS1GCLBX1	Impedance Isolation	G. E.
CR5	41100000	Diode, Zener - #Z78	10 Volt Reference Diode	Schauer
F1	31010001	Fuse, 1 Amp., #3AG 250V, Slo-Blo	Overload Protection	Littell
LS1	20006003	Bulb, Tungsten 6.3 Volt, 4.0 Amp. #1561	Source Lamp	G. E.
LS2	20014000	Bulb, Tungsten 14 V., .20 Amp. #1487	Antifatigue Lamp	G. E.
M1	24000600	Meter, 0-4.0 Density 100 μ a, 6000 Ohms Impedance	Density Indicator	Weston
R1	36507000	Resistor, Carbon. 500M Ohm, 1 Watt, $\pm$ 10%	Grid Bias	IRC
R2	36104001	Resistor Fixed, Comp. 100K Ohm, 1/2 Watt, $\pm$ 10%	Plate Load	Allen-
R3	36123000	Resistor Fixed, Comp. 12K Ohm, 1/2 Watt, $\pm$ 10%	B+ Divider	Allen-
R4-S2	36104000	Resistor, Comp., Variable w/On-Off Switch 100K Ohm, 2 Watt, Type JSU	Zero Adjust	Allen-
R5	36823000	Resistor, Fixed, Comp. 82K Ohm, 1/2 Watt, $\pm$ 10%	Grid Bias, Volt. Divider	Allen-
R6	36394000	Resistor Fixed, Comp. 390K Ohm, 1/2 Watt, $\pm$ 10%	Plate Load	Allen-
R7	36823000	Resistor, Fixed, Comp. 82K Ohm, 1/2 Watt, $\pm$ 10%	Cathode Bias, Volt. Divider	Allen-
R8	36223000	Resistor Fixed, Comp. 22K Ohm, 1/2 Watt, $\pm$ 10%	Cathode Bias Divider	Allen-
R9	36222000	Resistor, Fixed, Comp. 2.2K Ohm, 2 Watt, $\pm$ 10%	B+ Volt. Divider	Allen-
R10	36224000	Resistor, Fixed, Comp. 220K Ohm, 1/2 Watt, $\pm$ 10%	Screen Bias	Allen-
R11	36902000	Resistor, Fixed, Wirewound 9K Ohm, 10 Watt, $\pm$ 10%	B+ Volt. Divider	Koolot
R12 thru R20	36224000	Resistor, Fixed, Comp. 220K Ohm, 1/2 Watt, $\pm$ 10%	Dynode Volt. Dividers	Allen-
R21	36474000	Resistor Fixed, Comp. 470K Ohm, 1/2 Watt, $\pm$ 10%	B+ Voltage Divider	Allen-
R22	36254000	Resistor, Comp., Variable 250K Ohm, 2 Watt, Type JU	Meter Zero Bucking Adjust	Allen-
R23	36165000	Resistor, Fixed, Comp. 1.6M Ohm, 2 Watt, $\pm$ 5%	High Voltage Divider	Allen-
R24	36103001	Resistor, Comp., Variable 10K Ohm, 2 Watt, Type JU	Meter Shunt, Calibration Adjust	Allen-
R25	36682000	Resistor Fixed, Comp. 6.8K Ohm, 1/2 Watt, $\pm$ 10%	Meter Shunt	Allen-

REPLACEABLE PARTS LIST
TD-100A
ELECTRICAL - ELECTRONIC

Qty.	Part No.	Name of Part and Description	Function	Manufacturer
6	36243000	Resistor, Fixed, Comp. 24K Ohm, 1/2 Watt, $\pm 5\%$	High Voltage Divider	Allen-Bradley
7	36103000	Resistor, Comp., Variable 10K Ohm, 2 Watt, Type JU	Cut-In Adjust #1	Allen-Bradley
8	36254000	Resistor, Comp., Variable 250K Ohm, 2 Watt, Type JU	Effect Adjust #1	Allen-Bradley
9	36252000	Resistor, Comp., Variable 2.5K Ohm, 2 Watt, Type JU	Cut-In Adjust #3	Allen-Bradley
0	36254000	Resistor, Comp., Variable 250K Ohm, 2 Watt, Type JU	Effect Adjust #3	Allen-Bradley
1	36103000	Resistor, Comp., Variable 10K Ohm, 2 Watt, Type JU	Cut-In Adjust #4	Allen-Bradley
2	36254000	Resistor, Comp., Variable 250K Ohm, 2 Watt, Type JU	Effect Adjust #4	Allen-Bradley
3	36252000	Resistor, Comp., Variable 2.5K Ohm, 2 Watt, Type JU	Cut-In Adjust #2	Allen-Bradley
4	36254000	Resistor, Comp., Variable 250K Ohm, 2 Watt, Type JU	Effect Adjust #2	Allen-Bradley
5	36682000	Resistor Fixed, Comp. 6.8K Ohm, 1/2 Watt, $\pm 10\%$	Impedance Matching	Allen-Bradley
6	36223000	Resistor, Fixed, Comp. 22K Ohm, 1/2 Watt, $\pm 10\%$	Calibration Shunt	Allen-Bradley
7	36020000	Resistor, Wire Wound, Adjustable, 2 Ohm, 10 Watt, $\pm 10\%$	Source Lamp Intensity Adjust	Ohmite
-S2	43010100	Switch, Interlock #V3-23	Safety Interlock	Micro Switch
	36104000	Resistor, Comp., Variable w/On-Off Switch 100K Ohm, 2 Watt, Type JSU	Zero Adjust	Allen-Bradley
	43010200	Switch, Antifatigue #11SML	Antifatigue	Micro-Switch
	43010204	Switch, Toggle #82022-HD	Source Lamp Intensity Adjust	AM&H
	44000100	Power Transformer, M-124C	Power Transformer	Electrical Windings
	46000000	Tube Vacuum - 12AU7A	Twin Med. Mu Triode	RCA
	46000001	Tube, Vacuum - 6GW6A or 6DQ6B	Power Pentode	RCA
	46000002	Tube, Vacuum - 1B3GT	High Voltage Rectifier	RCA
	46000003	Tube, Vacuum - 6X4	B+ Rectifier	RCA
	46000004	Tube, Volt Reference - 0A2	150V. Regulator	RCA
	46000005	Tube, Volt Reference - 5651	90V. Regulator	RCA
	46000007	Photo Tube, Vacuum, 4471	Photomultiplier	RCA
	05818300	Line Cord, Gray	Power Cord for 115 or 230 V.	Macbeth
	40020001	Fuse Holder #341001-3AG	Fuse Holder	Littelfuse
	09010001	Jack, Dynode Voltage	Test Jack	E.F. Johnson Co.
	09010002	Jack, Dynode Voltage Red, #105-252-1	Test Jack	E.F. Johnson Co.
	40020000	Socket, Min. Screw Base #5-19XP34	Antifatigue Lamp Socket	Leecraft

REPLACEABLE PARTS LIST

TD-100A

OPTICAL

Desig.	Part No.	Name of Part and Description	Function	Manufactur
Visual	55010602	Filter, Wratten - #106W .860 Dia.	Visual Filter	Eastman
Neutral Density	56-----	Filter Pack, Wratten #96 N.D. .860 Dia.	Trimming Filters	Eastman Ko
	56290001	Filter, 2.90 $\pm$ 0.10 Flashed Silver Density x 1.000 Dia.	Calibration Reference	Eastman Ko
	27000000	Mirror, Front Surface	Folding Mirror	Macbeth
L1	27000300	Lens, Double Convex 34mm Dia. x 37.9mm F.L.	Imaging Lens	Macbeth
L2	27000200	Lens, Equi-Convex 28mm Dia. x 28mm. F.L.	Collection Lens	Macbeth
	27000500	Heat Absorber #PPG2043X/HAP-26 (3mm Thk.)	Absorb Heat	Macbeth
	27000800	Dichroic Filter #90-7-700, 1.750 Dia.	Infrared Cutoff	Macbeth
	27000100	Pot Opal	Diffuser, Collection Cone	Macbeth

MECHANICAL

	21003300	Screw, Cover	Retain Cover	Macbeth
	21003200	Knob, Control	Front Controls	Macbeth
	51800200	Washer, Felt	Front Panel Protection	Macbeth
	50000100	Spring, Torsion	Snout Return	Macbeth
	50000200	Spring, Torsion	Snout Tension	Macbeth
	51400300	"O" Ring #5-017C356-4	Aperture Light Seal	Parker
	51000000	Ball, Nylon - 3/32 Dia.	Calibration Reference Control	Ace Plast
	50000300	Spring, Detent	Calibration Reference Control	Macbeth

FIGURE 1

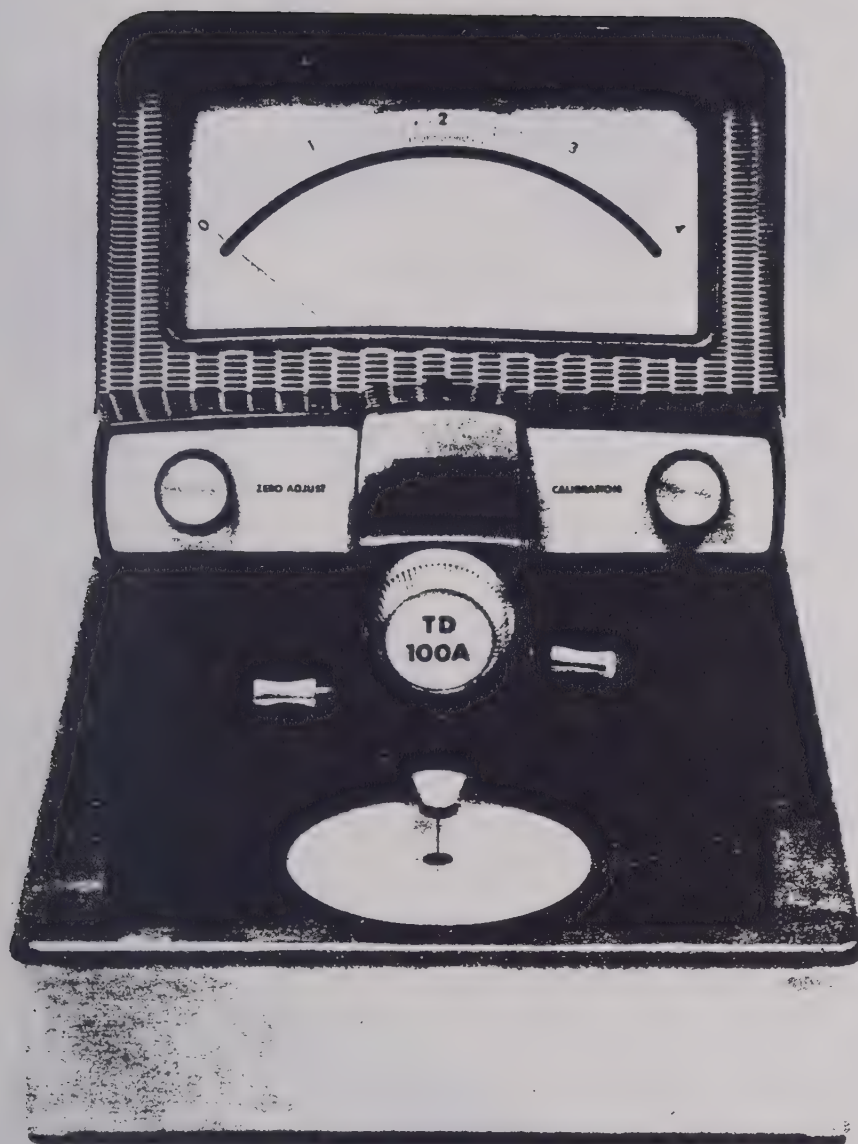


FIGURE 2

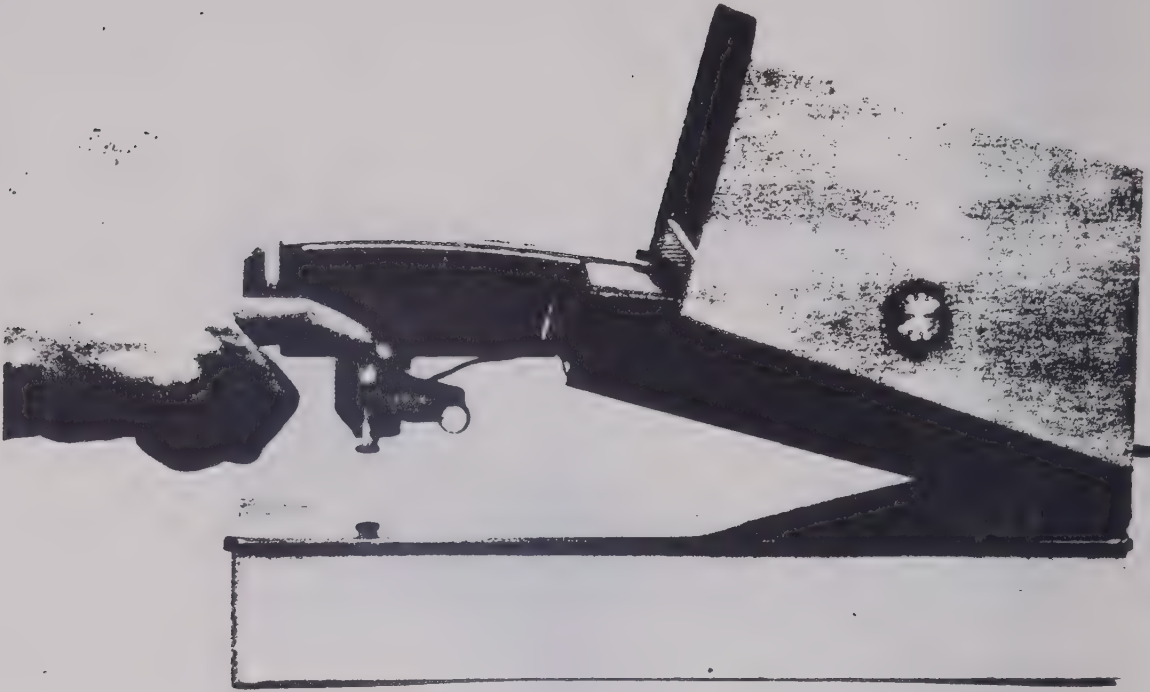
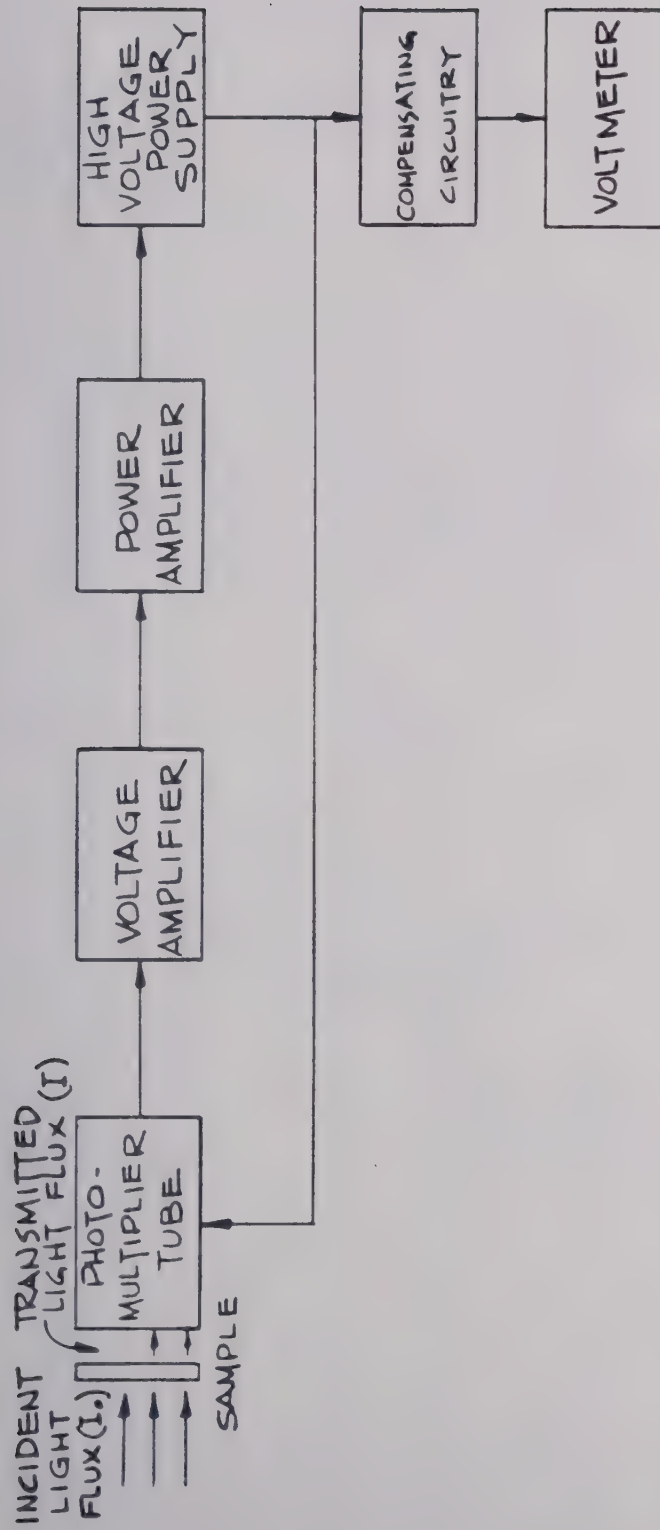
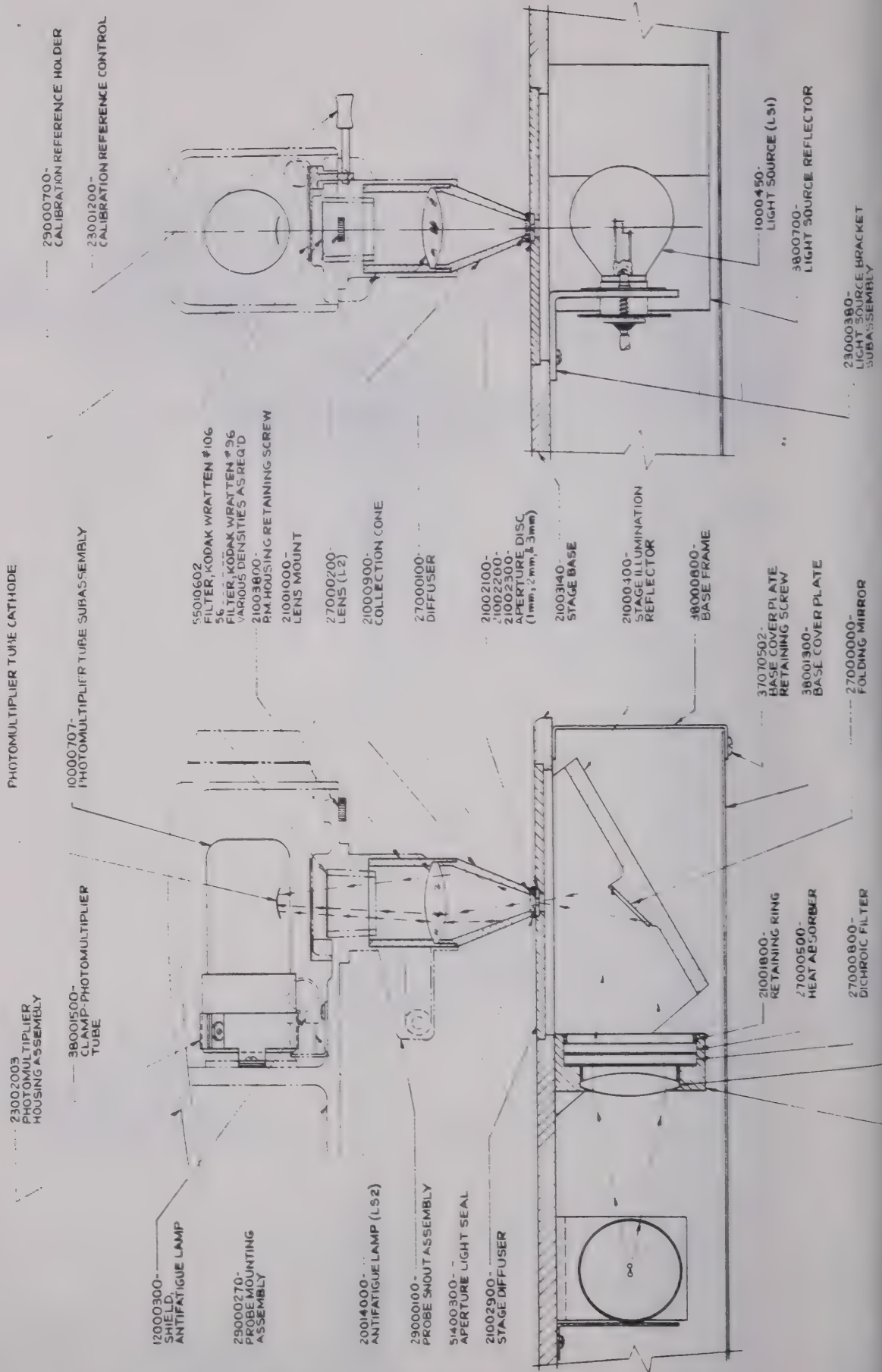


FIGURE 3



SYSTEM BLOCK DIAGRAM

FIGURE 4



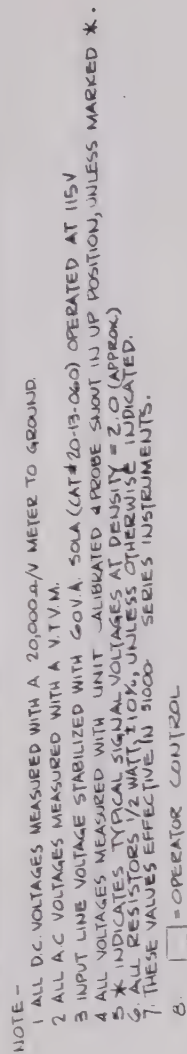
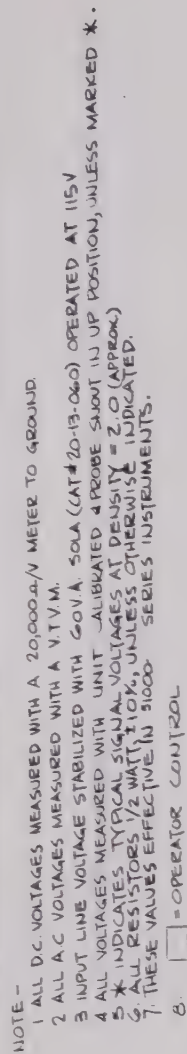
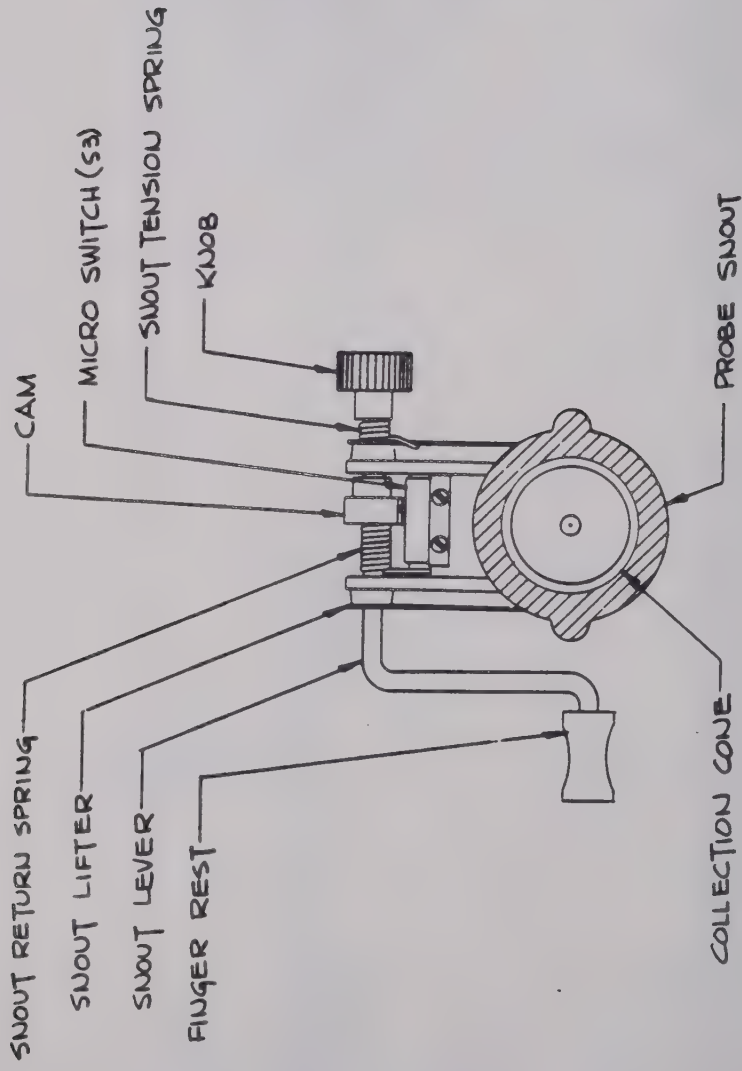
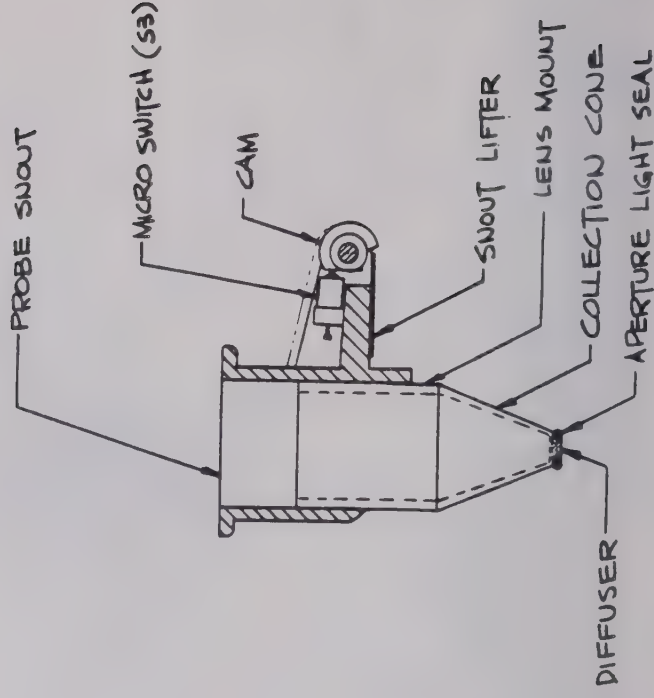


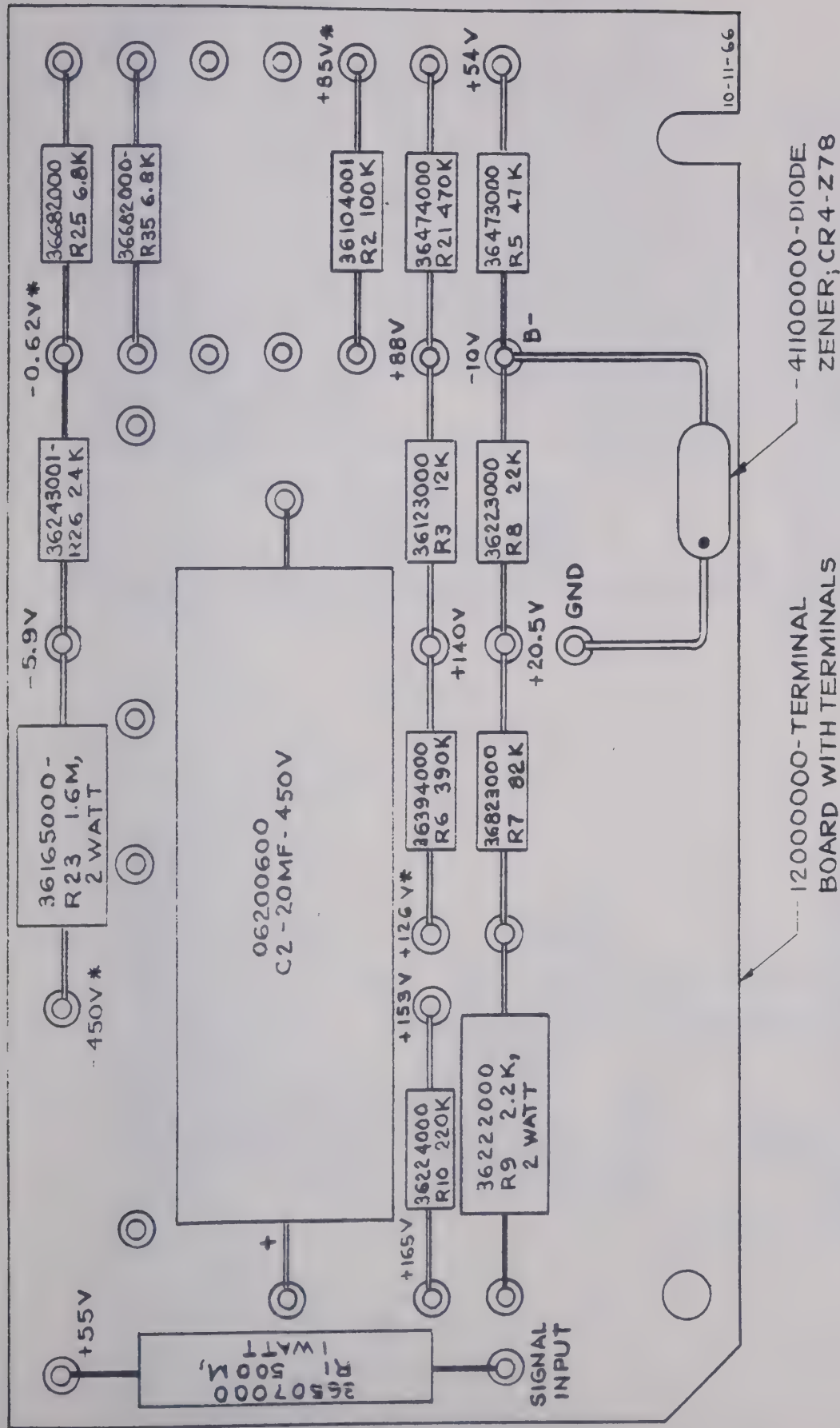
FIGURE 6



GA - TOP VIEW



GB - PARTIAL SECTION - SIDE VIEW



NOTES:

1. ALL VOLTAGES TAKEN WITH 20,000 OHM/V.D.C. METER TO GROUND.
2. INPUT LINE VOLTAGE STABILIZED WITH 60 VA SOLA (SER. # 20-13-060)
3. ALL VOLTAGES MEASURED WITH TD-100A CALIBRATED & PROBE SNUOT IN UP POSITION, EXCEPT THOSE MARKED *.

*TYPICAL SIGNAL VOLTAGES

FIGURE 8

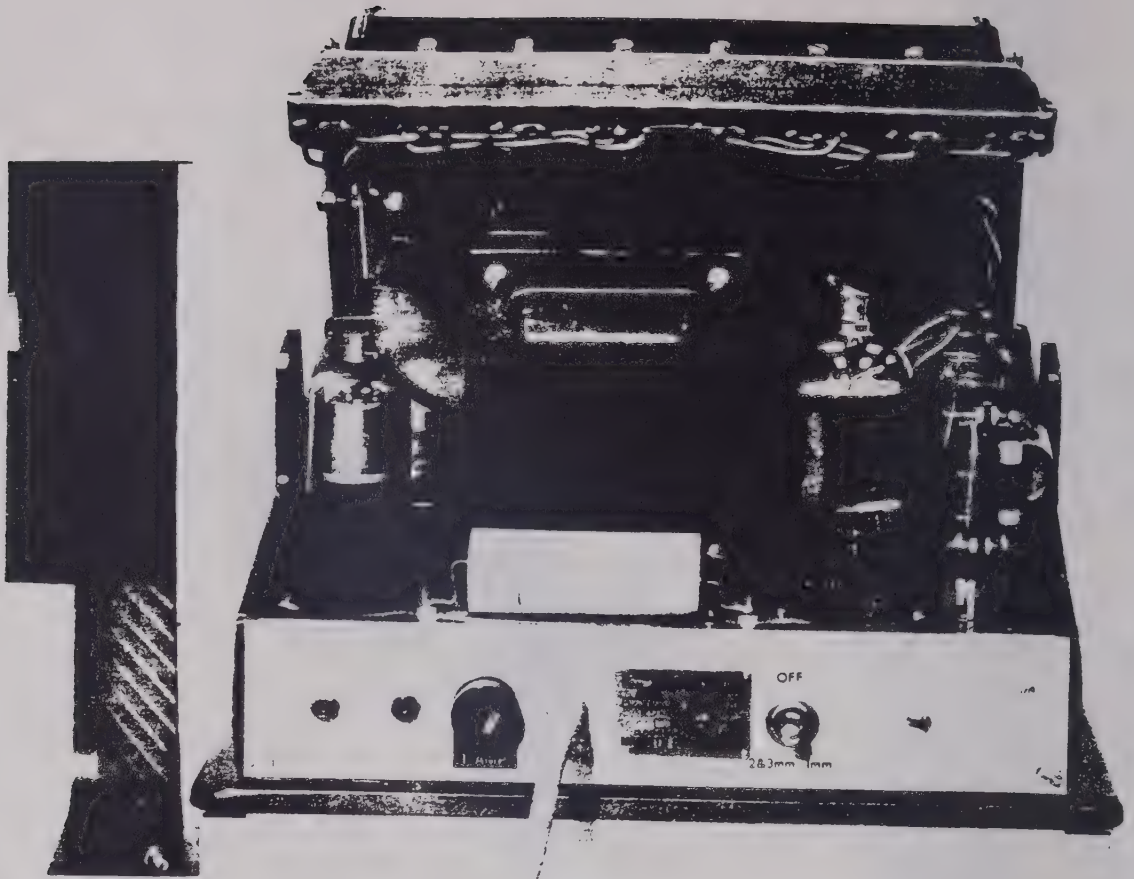


FIGURE 9

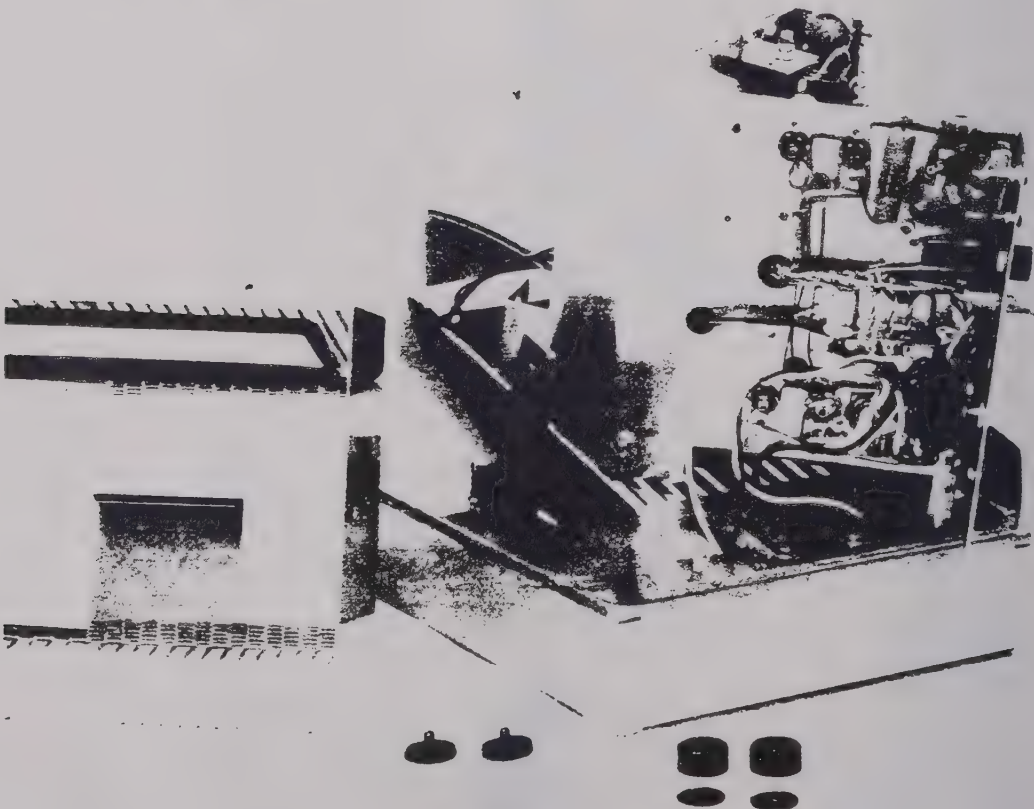


FIGURE 10

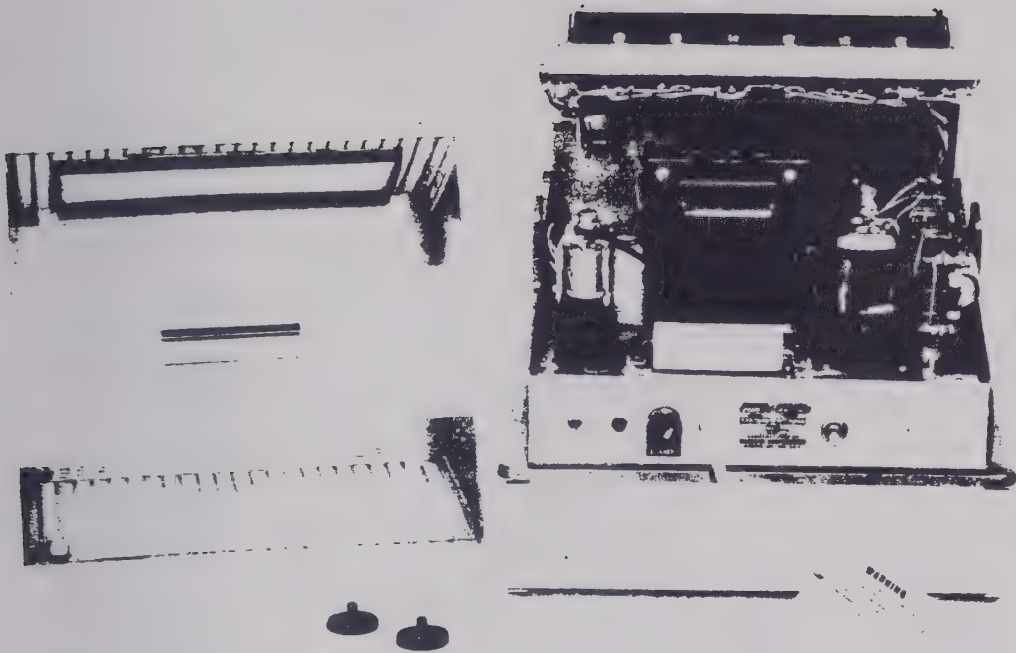


FIGURE 11

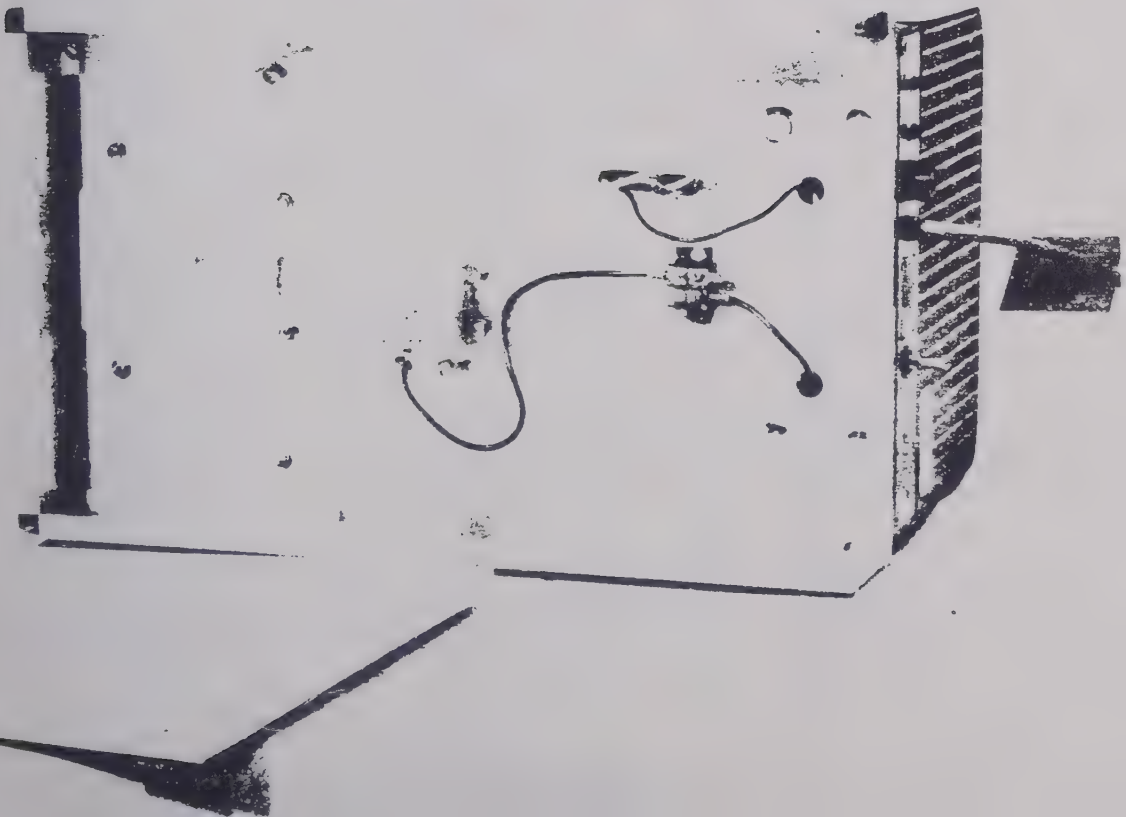


EXHIBIT A

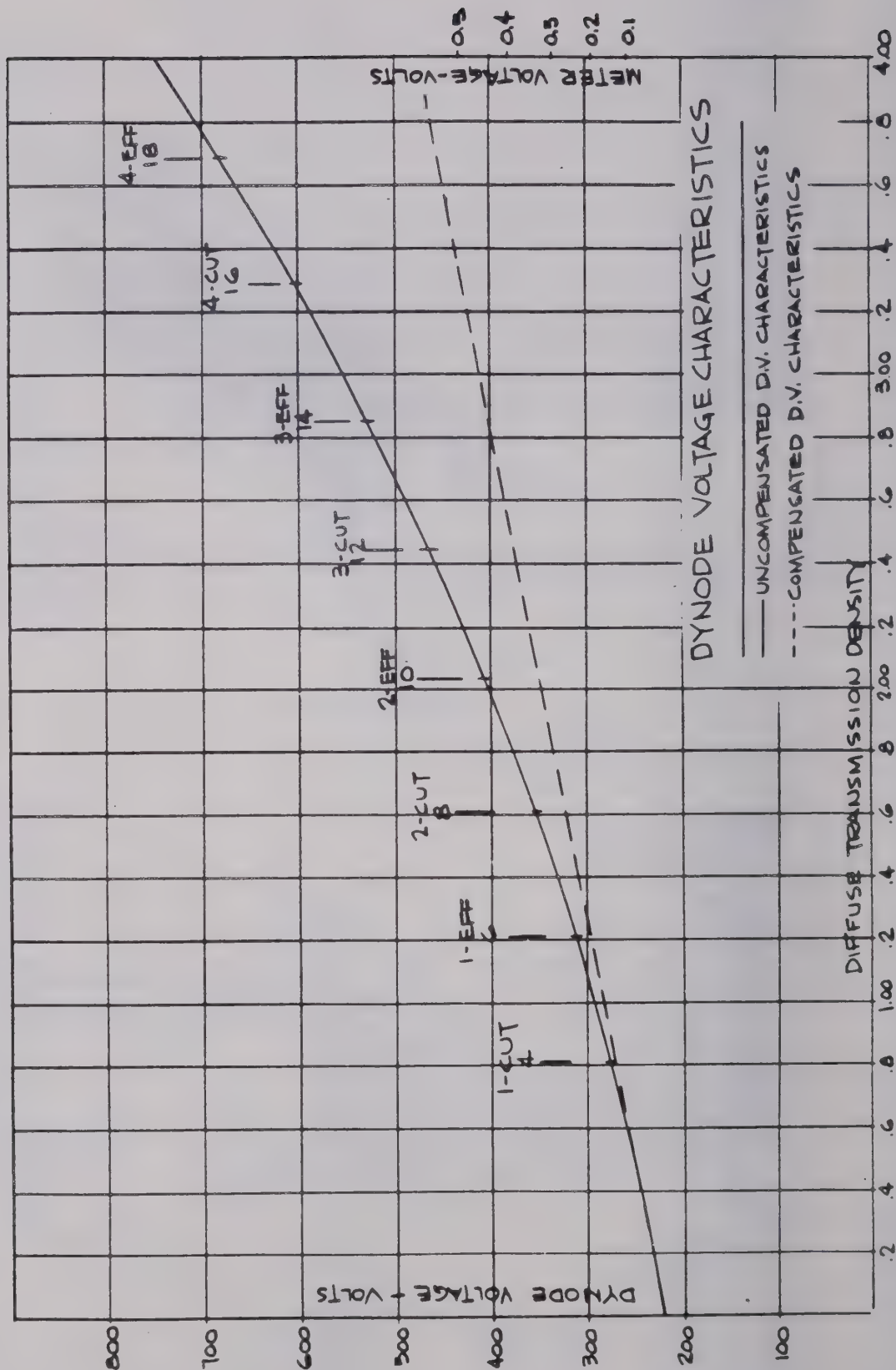


EXHIBIT B

TROUBLE SHOOTING GUIDE

Effect at Zero	Check	Fault
Meter Reads High Off Scale		12AU7 Open or out of Socket
Meter Reads High Off Scale	Read Approx. -30V. At 0A2 Pin-2, 4, and 7	IN1986 Open (CR-4)
Meter Reads High Off Scale	Meter Reads Low off Scale when 12AU7 Pin-2 Grounded.	931-A out of socket or cable conn. open
Meter Reads High Off Scale	Read Approx. --70V at 6X4 Pin-7	6X4 open or out of socket
Meter Reads High Off Scale	Read 0.0V. A.C. at 6X4 Pin-1 or 6	Transformer (T1) open. 290VAC secondary
Meter Reads Approx. 2.0 Den.	Read approx. +150V, at 5651 Pin-1,5	5651 Open or Out of Socket
Meter Reads Approx. 2.0 Den.		500 MEG. Shorted (R1) (Approx. 1.0 MEG.)
Meter Reads Approx. Zero	Read Approx. +300V, at 0A2 Pin-1 and 5	0A2 Open or Out of Socket
Meter Reads Approx. Zero, but out of Calib.	Read less than + 120V. at 0A2 Pin-1, 5	20 MF. (C2) shorted (Approx. 10K)
Meter Reads Below Zero		500 MEG (R1) Open
Meter Reads Below Zero	Read 0.0.V. at Dynode Volt Jacks	1B3 Open, out of socket, or open High volt. trans. winding (T1)
Meter Reads Below Zero, but Dynode Volt, too High	Read Approx. +108V, at 6GW6 Pin-8	6GW6 Open or out of Socket
Meter Reads Below Zero	Read 0.0V. at 0A2 Pin-2, 4, 7	IN1986 Shorted (CR-4) 0.0 OHMS

EXHIBIT C
D. C. VOLTAGE AND RESISTANCE MEASUREMENTS
D. C. Volts to Ground

Point of Measurement	Probe Up	Probe Down (2.0 Density)	Resistance to Ground (Ohms)
V1 - 12AU7			
Pin 1	85.0*	84.7*	190 K
2	Signal Input	Signal Input	>50 M
3	20.5	20.5	32 K
6	120.0*	126*	450 K
7	85.0*	84.7*	190 K
8	88.0	88.0	70 K
V2 - 6GW6-A			
Pin 4	153	153	300 K
5	120.0*	126.0*	450 K
8	140	140	62 K
Plate Cap	1120*	865*	>50 M
V3 - 1B3			
Plate Cap	-230*	-450*	900 K
V4 - 6X4			
Pin 7	270	270	72 K
V5 - 0A2			
Pin 1, 5	140	140	62 K
2, 4, 7	-10	-10	360 Ohm
V6 - 5651			
Pin 1, 5	88.0	88.0	70 K
2, 4, 7	0.0	0.0	0.0
V7 - 931-A			
Pin 9	0.0	0.0	0.0
10	Signal Input	Signal Input	>50 M
11	-230*	-450*	900 K

*Typical Signal Voltages

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